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Integration of an Automated Valet Parking Service into an Internet of Things Platform

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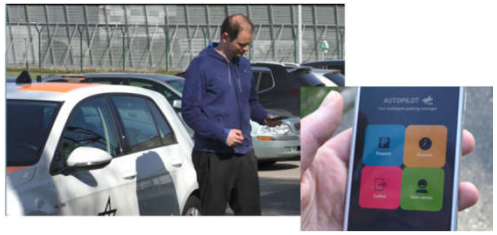
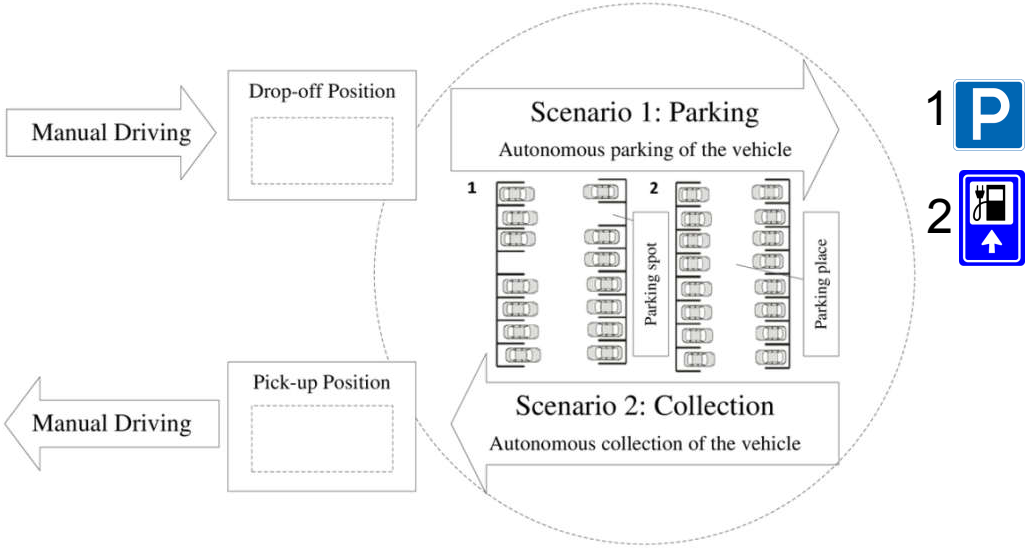
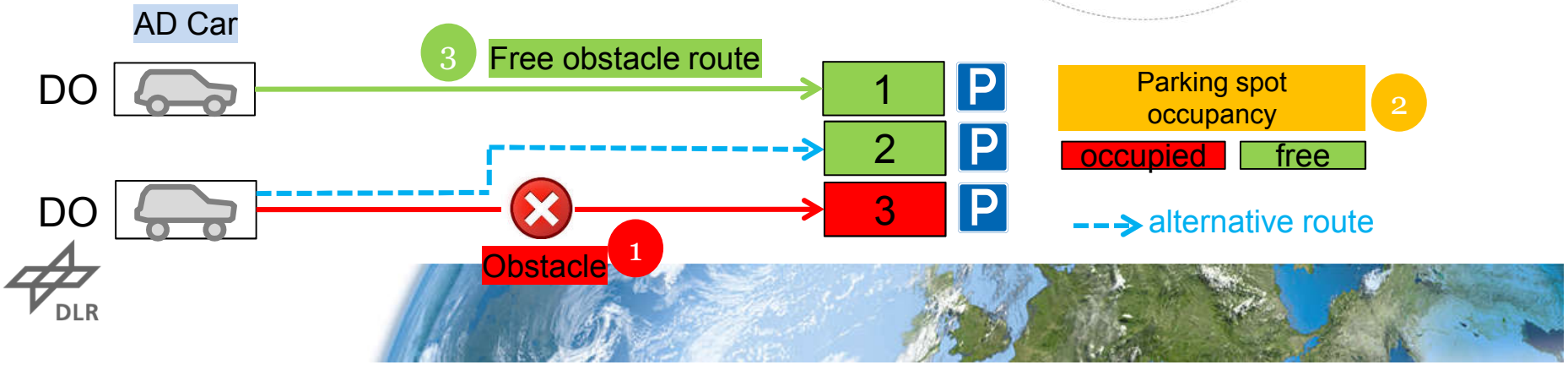
Automated Valet Parking (AVP)

- The car is enabled (through IoT) to drive unmanned (autonomously) from the **drop-off (DO)** point to a **parking spot (parking scenario),** and to return to the **pickup (PU)** point (**collection scenario**) to the driver on command using mobile APP







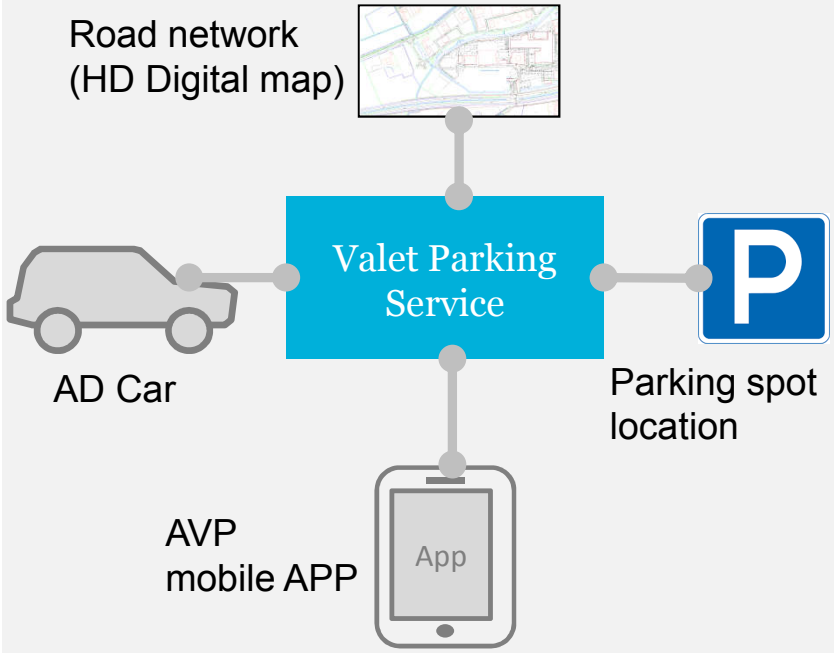
Automated Valet Parking (AVP)

- **This offers**:
  - Comfort service to car drivers (no time lost finding a parking spot)
  - More efficient use of space on parking lots (cars can be parked closer)
  - Less damage to cars during parking
  - Optimization of logistics and reducing congestion in and towards parking area
  - More efficient use of (electro-vehicle) EV charging spots

Automated Valet Parking Implementation

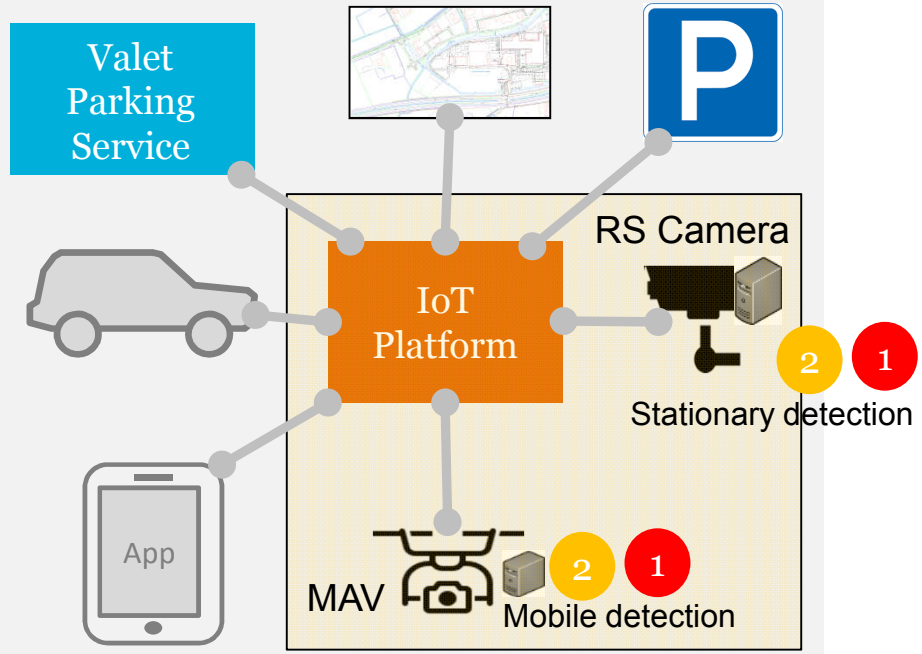
Option 1: without IoT

- Parking spot exploration is needed



Option 2: With IoT

- No need of parking spot exploration



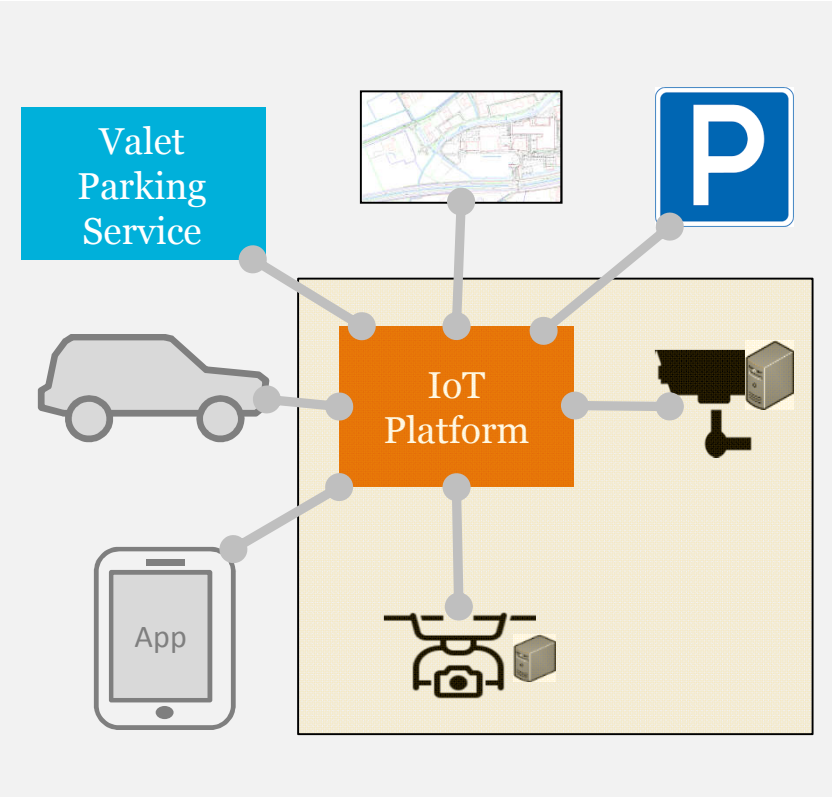
MAV: Micro Aerial Vehicle

Parking spot Occupancy detection 2

Obstacle detection 1

Requirements for the IoT Integration of AVP

Option 2 has been implemented



Requirements

- IoT **concept** of AVP development
- IoT **interface** implementation on the IoT devices and application side to allow the communication with the IoT platform
- IoT (standardized) **data model** specification for all involved IoT devices (vehicle, MAV, camera, etc..)
- Adaptation of **automation functions** in the vehicle to support IoT data
- Define the **communication workflow** between system components

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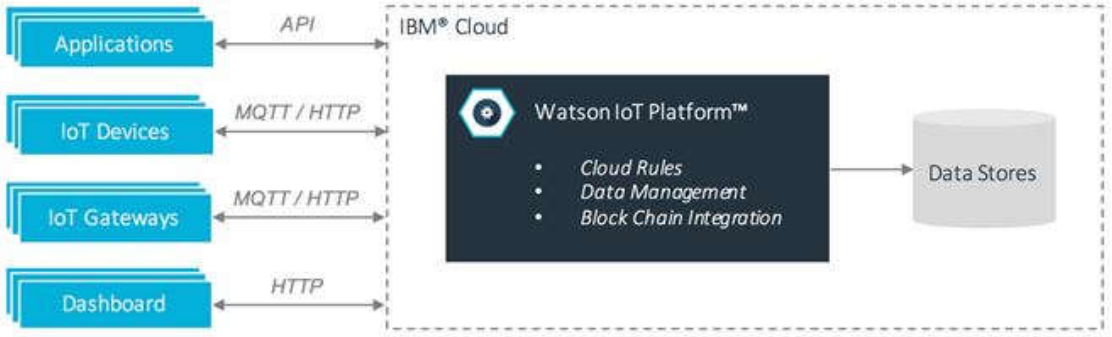
IoT Platform

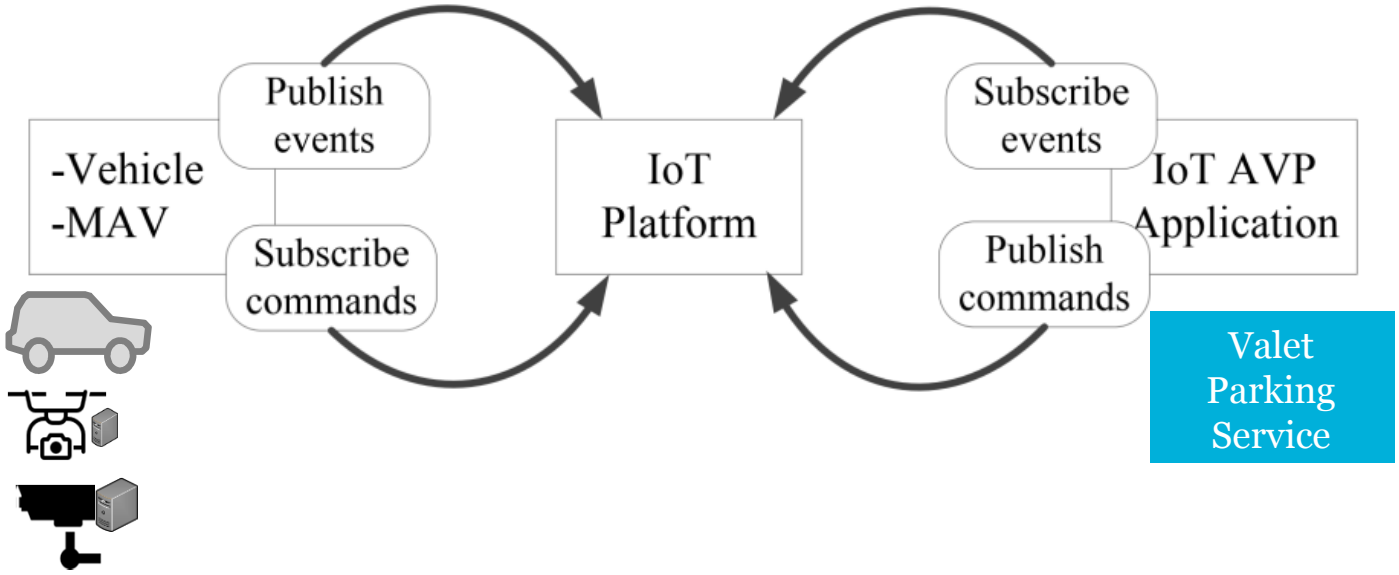
- IoT Platform: is an brocker or middleware that sits between IoT devices and application and connects a wide variety of devices, applications etc…
- Core functionalities: API Gateway, cloud service, device integration, device management, data management, data analysis, data publication, data subscription, service operation and management
- Interworking of IoT platforms possible
- Enables **data sharing**
- Communication protocols: MQTT, TLS, REST API or CoAPS
- Applied: Watson IoT platform



MQTT : Message Queuing Telemetry Transpor

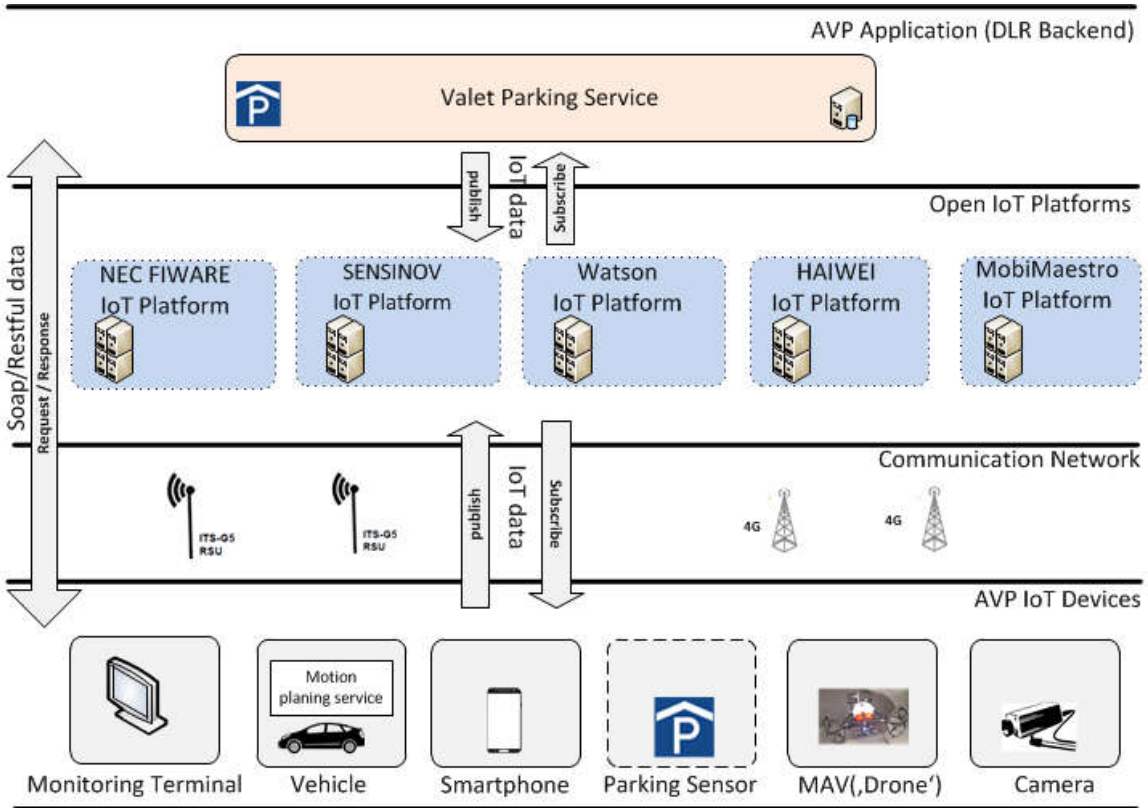
IoT device / Application
Publish / Subscribe Messaging

- Devices: IoT vehicle, IoT smartphone, MAV equiped with cameras
- Actions of application: publish events/commands, subscribe events/commands
- Actions of devices: publish events, subscribe commands

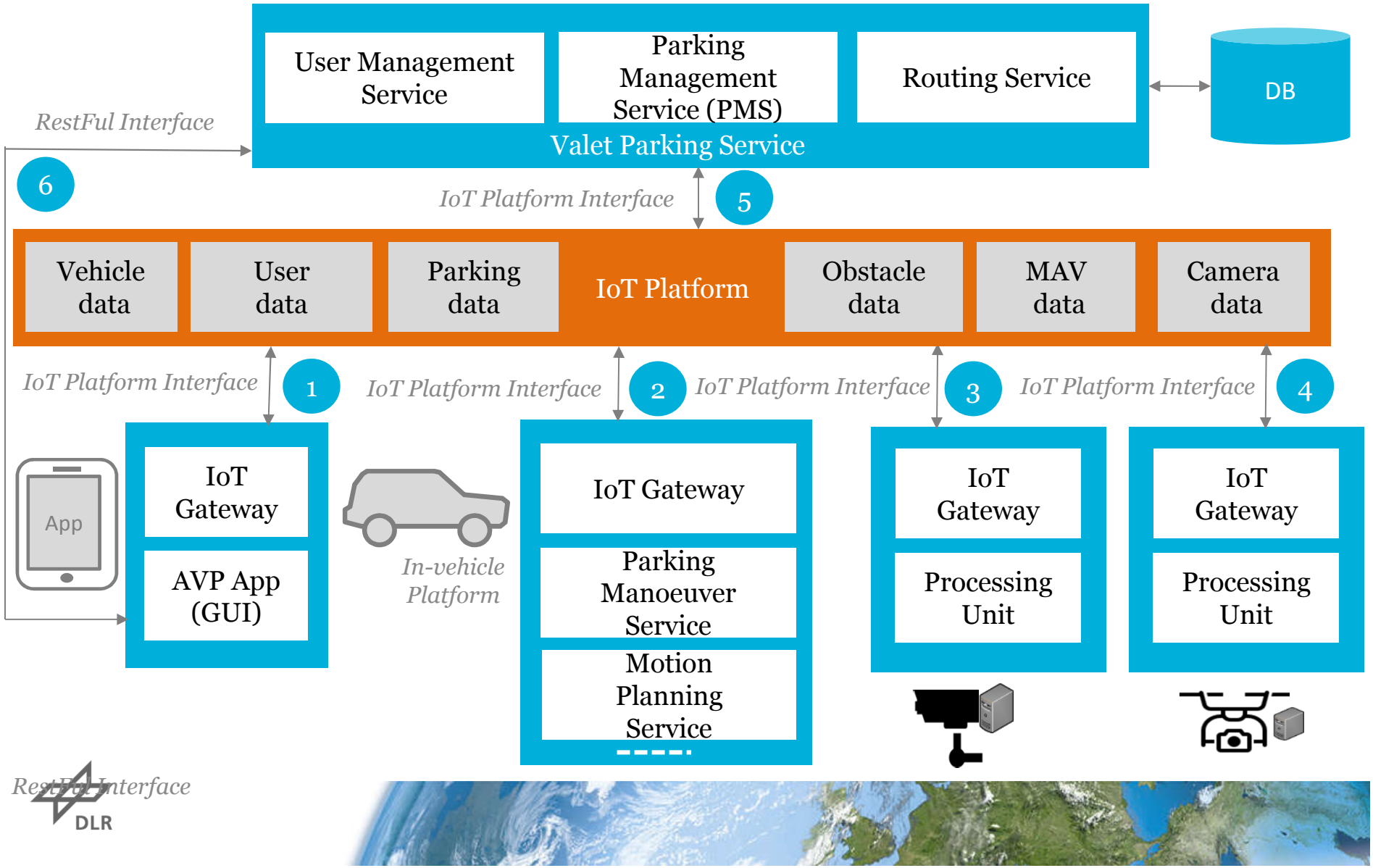


System architecture - overall

- The AVP system: a backend system, a IoT platform and some IoT devices such as smart phone, IoT vehicle, parking spot, MAV and camera



System components and IoT communication interfaces

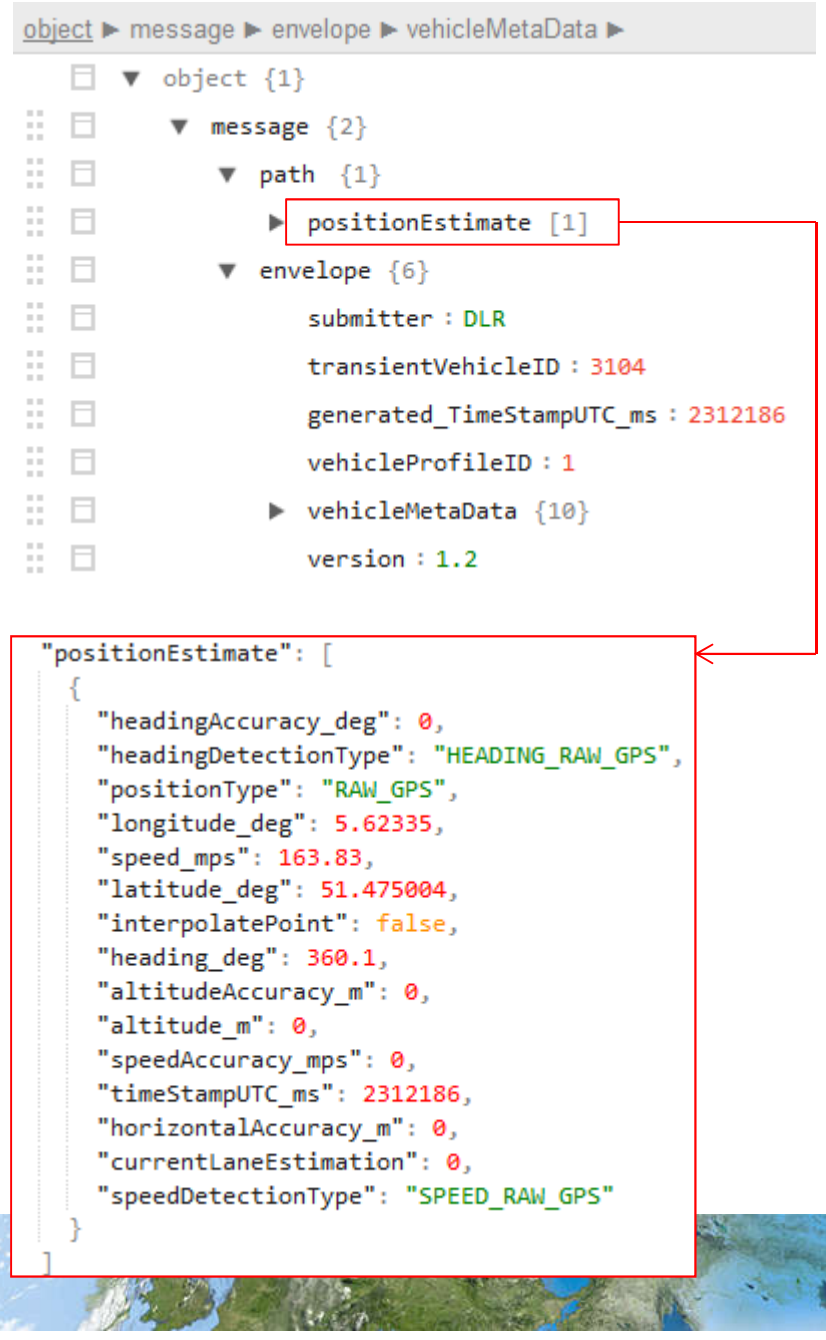


AVP IoT event data model

1. AVP IoT event message for vehicle
   - *AVPStatus*
   - AVPChargingStatus
   - *ParkingSpotDetection*
   - *PositionEstimate*

2. AVP IoT event message for MAV
   - Parking spot occupancy detection
   - Obstacle detection

3. AVP IoT event message for camera
   - Parking spot dectection
   - Obstacle detection



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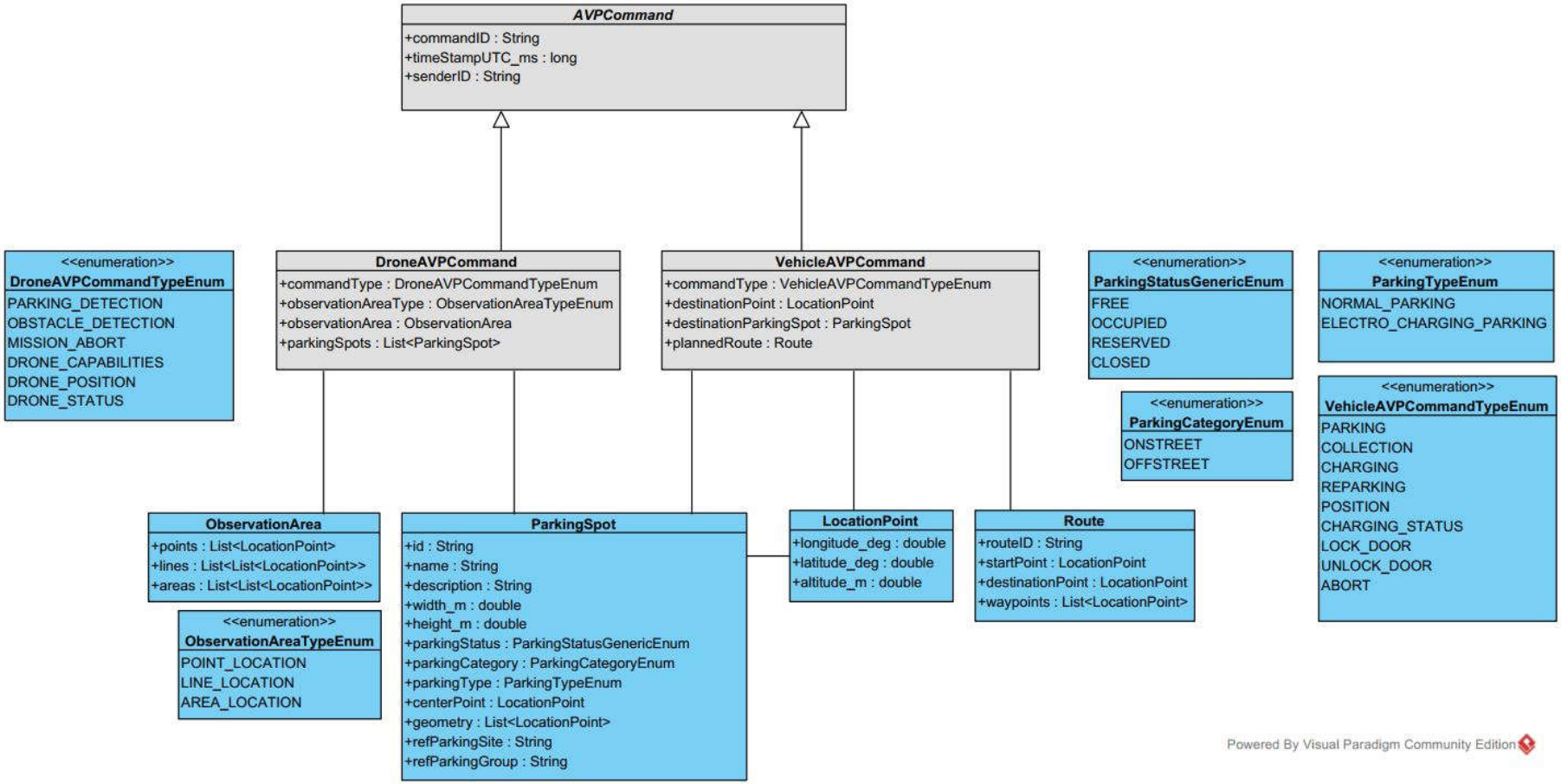
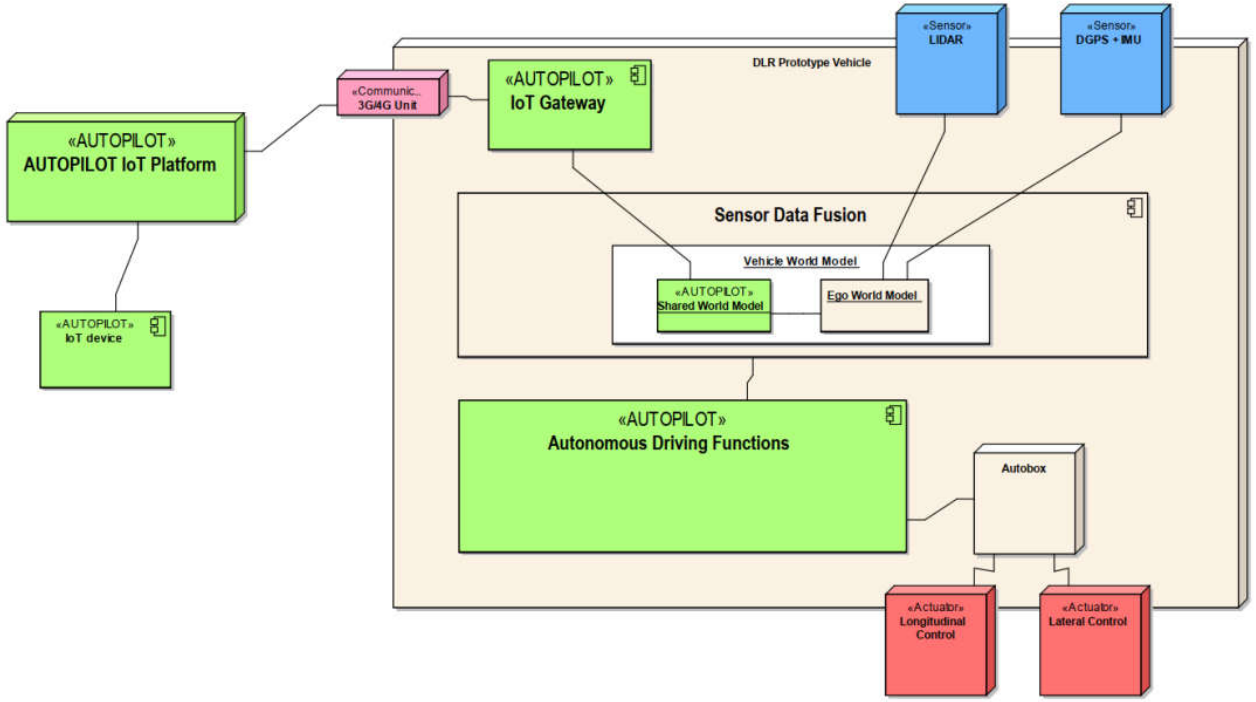
AVP IoT command data model

- *VehicleAVPCommand* and *DroneAVPCommand*



System implementation
IoT Device: Vehicle

- Test car: Volkswagen e-Golf
- Two separated computers for the different vehicle functions:
  - Autonomous driving functions
  - A sensor data fusion computer



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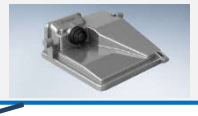
NEC Linkbird
V2X Communikation

Bosch Camera
Lane detection
Traffic sings
Object detection



NOVATEL SPAN-CPT
GPS + Glonass
IMU
DGPS (local reference)

DLR IPS-Box
Optical 3D-vision
IMS
D-GPS

Ultrasonic Sensors
Near range detection < 5m

SMS Radar
Front objects
Length: 70m
Azimut : ± 33°

IBEO Laserscanner
4 LUX + Fusion ECU
length : to 200m
Range: 85°

SMS Radar
Blind Spot detection
- Length 8m
- Azimut ± 70°

Rear objects
- Length 120m
- Azimut ± 8°

Bosch Radar
Front objects
Lengths: ~ 160m
Azimut : + 6°

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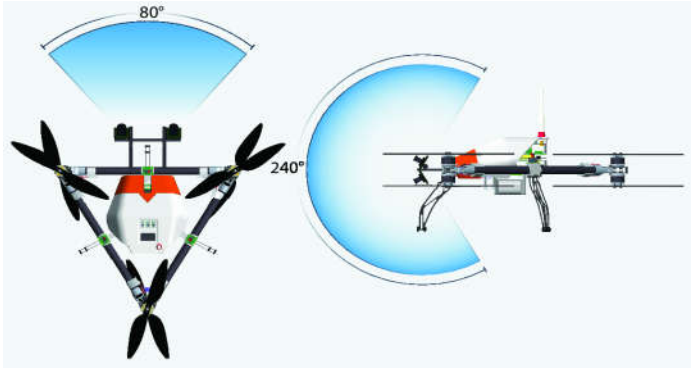
System implementation
IoT Device: MAV

- MAV and ground-station PC act as IoT device.
- MAV is able to navigate autonomously in outdoor as well as indoor (GPS-denied) environments.
- IoT AVP application sends list of parking spots for occupancy checking.
- Using input from cameras and deep-learning the occupancy status of parking spots is determined.



- Custom coaxial tricopter design by DLR
- Size & weight: 68x68x30 cm, 2.6kg
- Flight time: approx. 10min
- Sensors: 2 stereo camera pairs, IMU
- Single camera field of view: 125°x80°
- Total field of view: 240°x80°
- Computers: Intel i7, FPGA (stereo processing), BeagleBoneBlack (ARM-based)

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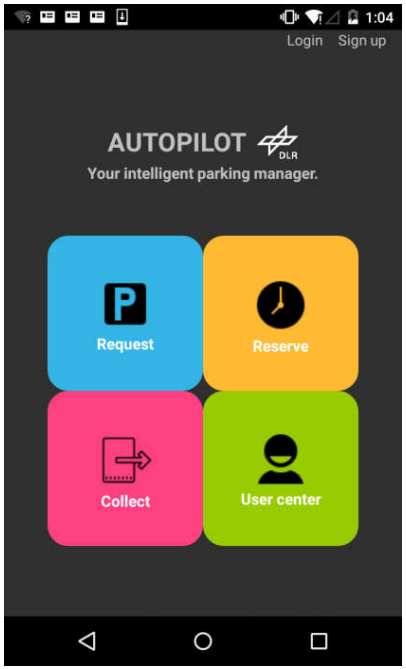
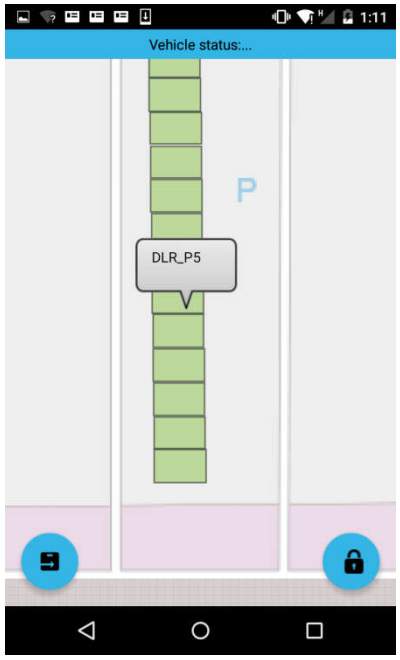
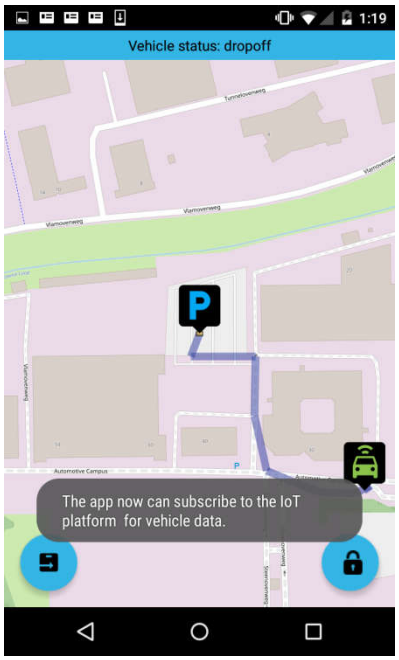
System implementation
User Frontend: Smart Phone Application

- Developed with Android API 26
- Consists of a SOAP web service interface and an IoT interface
- The integrated map is Open Street Map

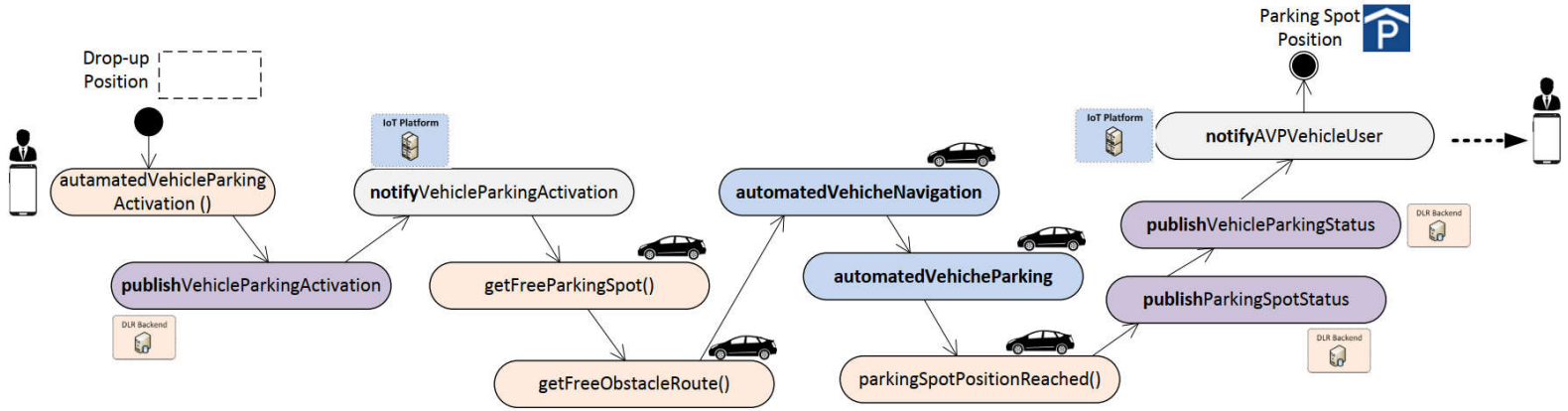




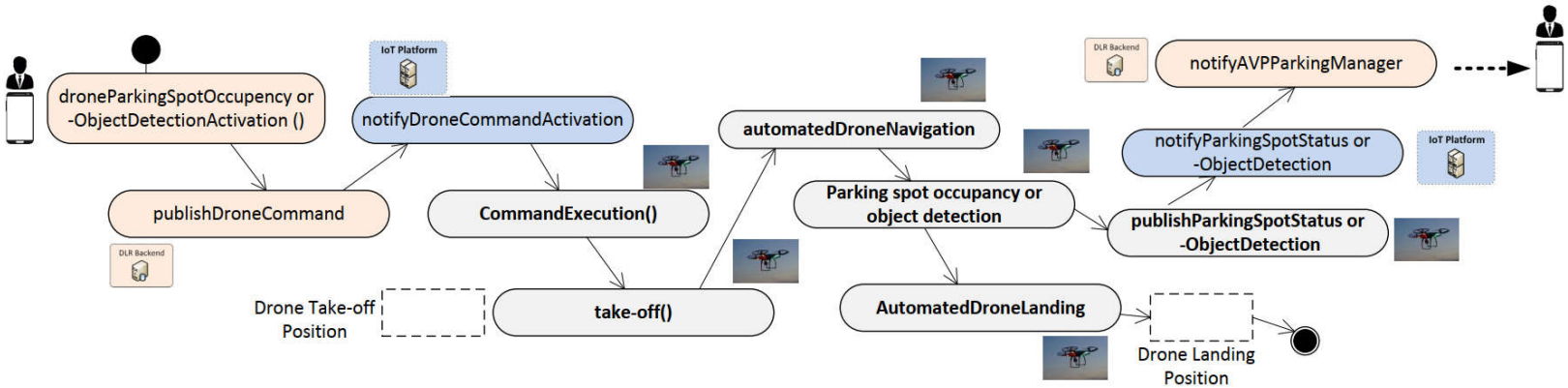


System evaluation
Use cases

- *Vehicle parking*



- *Parking spot occupancy and obstacle detection with the MAV*



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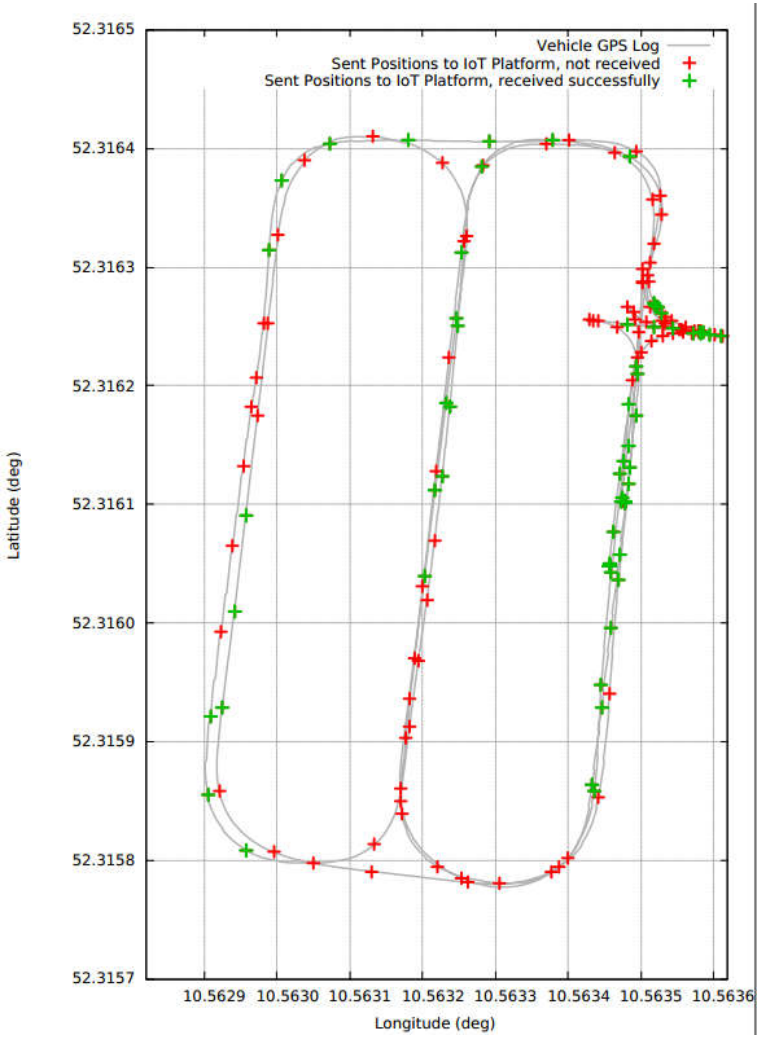
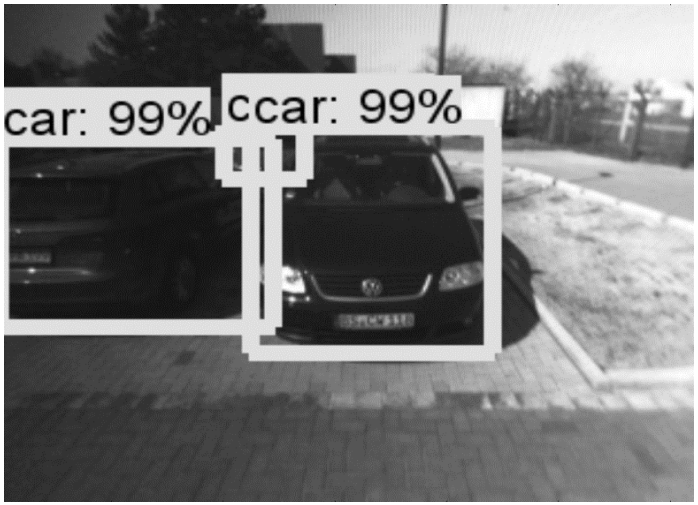
System evaluation
Testing processes (1)

- DLR test site in Brunswick, Germany
- Vehicle positions are regularly transmitted
- Data loss is around 50% at distances between 50 m and 100 m between car and wireless access point



System evaluation
Testing processes (2)

- The status during flight in real-time at 0.5 Hz
- Parking spot occupancy detection: state of the art deep learning methods



Demonstration video of the pre plugfest in Brunswick, Germany: Link

Conclusion

- Present a AVP system integrated into a IoT platform
- Different components which are operating all together in a complete driving and application test
- The test shows all the components being run together
- Next steps:
  - Improvement of the system functionalities
  - Preparation of the next piloting in the test site in Germany and AUTOPILOT pilot site in December 2018, March and June 2019 in Brainport, the Netherlands
  - Technical evaluation of the AVP use case

Thanks for your attention!

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AUTOPILOT

AUTOmated driving **P**rogessed by **I**nternet **O**f **T**hings

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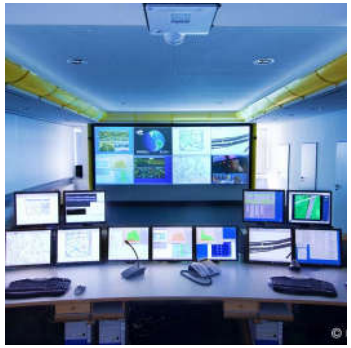

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